Characterization and Evaluation of *Saururus cernuus* Emulgel for Antibacterial Activity

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Abstract: The purpose of this research was to characterize and evaluate a topical Emulgel formulation derived from *Saururus cernuus*, a plant known for its antibacterial properties. The plant was collected, and the extractive values were determined. Phytochemical analysis confirmed the presence of flavonoids and tannins, bioactive compounds that exhibit antibacterial activity. The Emulgel formulation was prepared and thoroughly analyzed for parameters such as pH, viscosity, and spreadability. An in vitro drug release study showcased a sustained release profile of the active components, ensuring prolonged antibacterial activity. The antibacterial effectiveness of the Emulgel was validated against Staphylococcus aureus and Escherichia coli using the disc diffusion method, demonstrating broad-spectrum antibacterial potential. Across all tests, the formulation exhibited consistency, suggesting robustness in the formulation process. While the results are promising, further in vivo studies are recommended to confirm the formulation's efficacy and safety on actual skin conditions.

Keywords: *Saururus cernuus*; Emulgel; Antibacterial Activity; Topical Formulation; Disc Diffusion Method; Phytochemical Analysis; In Vitro Drug Release; Viscosity; pH; Spreadability

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Introduction

The rapidly escalating challenge of antimicrobial resistance, with the concomitant need for the development of new antibacterial agents, calls for a vigorous exploration of alternative resources beyond synthetic antibiotics [1]. Nature provides an abundant reservoir of bioactive compounds, particularly within the plant kingdom, where an array of species are known to harbor constituents with

significant antibacterial properties [2]. *Saururus cernuus*, also known as Lizard's tail, is one such plant species that has been employed in traditional medicine, notably for its antimicrobial and anti-inflammatory properties [3].

Saururus cernuus is a perennial herb that belongs to the Saururaceae family, native to Eastern North America. Its use in traditional medicine, especially by Native Americans, ranges from the treatment of inflammatory conditions, insect bites, kidney ailments, to venereal diseases [4]. Modern phytochemical investigations have identified a variety of active constituents in *Saururus cernuus*, such as flavonoids, diterpenes, and lignans, all of which potentially contribute to its medicinal attributes. However, despite these promising aspects, the therapeutic potential of *Saururus cernuus*, specifically its antibacterial properties, remains largely underexplored [5].

One possible approach to fully harness the medicinal benefits of *Saururus cernuus*, while ensuring enhanced skin permeation and patient compliance, is its formulation into an Emulgel. Emulgels are dual release systems that combine the properties of emulsions and gels, thus providing a potent medium for the delivery of hydrophobic drugs [6]. The unique composition of Emulgels facilitates drug penetration and allows for sustained release, making it an effective vehicle for the transdermal delivery of therapeutic agents [7]. In the case of *Saururus cernuus*, formulating it into an Emulgel could potentially amplify its antibacterial efficacy, while offering the advantages of ease of application and improved bioavailability [8].

This study aims to characterize and evaluate a novel *Saururus cernuus* Emulgel for its antibacterial activity [9]. The research will involve the extraction and characterization of bioactive compounds from *Saururus cernuus*, the formulation and optimization of the Emulgel, and the subsequent evaluation of its antibacterial activity against select bacterial strains [10]. It is anticipated that this study will provide pivotal insights into the potential application of *Saururus cernuus* emulgel as an effective antibacterial agent, thus offering a possible pathway towards addressing the pressing issue of antibiotic resistance [11].

Materials and Methods

Collection of Plants [12]

The plant material, *Saururus cernuus*, was collected from an identified and verified natural habitat during the plant's flowering stage, as it is believed to contain the highest concentration of bioactive compounds during

this period. The collected plant material was then be authenticated by a plant taxonomist, ensuring the accuracy of plant identification. The plant samples were thoroughly washed with water to remove dirt and other contaminants, followed by air-drying under shade at room temperature. The dried plant material was then be powdered using a mechanical grinder and stored in airtight containers until further use.

Preparation of Extract [13]

The dried and powdered plant material was subjected to a sequential extraction process using solvents of increasing polarity (hexane, ethyl acetate, and methanol). Approximately 500g of the powdered material was macerated with each solvent in a ratio of 1:5 (w/v) for 72 hours with occasional stirring. After 72 hours, the mixture was filtered, and the residue was re-extracted with the same solvent. The process was repeated until the filtrate becomes colorless. The combined filtrate was evaporated under reduced pressure using a rotary evaporator to obtain the respective extracts. The extracts was then be stored at 4°C until further use

Phytochemical Analysis [13, 14, 15]

Qualitative phytochemical screening will be performed on the different extracts to identify the presence of various classes of compounds such as flavonoids, tannins, saponins, alkaloids, terpenoids, and glycosides. Standard procedures will be followed for each test.

1. **Test for Flavonoids**: A few drops of dilute ammonia solution were added to a portion of the aqueous filtrate of the plant extract followed by the addition of concentrated sulfuric acid. A yellow coloration observed in the ammonia layer indicates the presence of flavonoids.

2. **Test for Tannins**: About 0.5g of the dried powdered sample was boiled in 20ml of water in a test tube and then filtered. A few drops of 0.1% ferric chloride solution were added and observed for brownish-green or a blue-black coloration.

3. **Test for Saponins**: About 2g of the powdered sample was boiled in 20ml of distilled water in a water bath and then filtered. The filtrate was shaken vigorously and observed for a stable persistent froth. The frothing is mixed with 3 drops of olive oil and shaken vigorously after which it is observed for the formation of an emulsion.

4. **Test for Alkaloids**: The extracts was stirred with a few drops of dilute Hydrochloric acid and filtered. The filtrate was tested with various alkaloid reagents like Mayer's reagent, Dragendorff's reagent, Wagner's reagent, and Hager's reagent.

5. **Test for Terpenoids (Salkowski test)**: Five milliliters of each extract was mixed with 2 ml of chloroform, and 3 ml of concentrated H2SO4 was carefully added to form a layer. A reddish-brown coloration of the interphase will indicate the presence of terpenoids.

6. **Test for Glycosides**: To 2 ml of the extract, 2 ml of glacial acetic acid containing one drop of ferric chloride solution will be added. This was underplayed with 1 ml of concentrated sulfuric acid. A brown ring at the interface was indicated a deoxysugar characteristic of cardenolides. A violet ring may appear below the brown ring, while in the acetic acid layer, a greenish ring may form just gradually throughout thin layer.

All these analyses aim to detect the possible active compounds responsible for the antibacterial activity of the *Saururus cernuus* extract.

Formulation of Emulgel [16]

Initially, the Carbopol 940 was dispersed in distilled water with continuous stirring until a homogeneous gel base was obtained. Triethanolamine was then added drop wise to neutralize the pH. The oil phase, comprising liquid paraffin, Span 80, Tween 80, and isopropyl myristate, was heated to 70°C. The *Saururus cernuus* extract, dissolved in a minimal amount of ethanol, along with methyl paraben and propyl paraben, was added to the oil phase. The oil phase was then added slowly to the aqueous phase with continuous stirring until a uniform Emulgel was formed.

Table 1- Formulae of Emulgel

Ingredient	Quantity (g)
Carbopol 940	1
Triethanolamine	0.4
Saururus cernuus Extract	1
Liquid paraffin	10
Span 80	2

Tween 80	2
Isopropyl myristate	5
Methyl paraben	0.2
Propyl paraben	0.1
Distilled water	To 100g

Evaluation Parameters

Physical Appearance [17]

The physical appearance of the Emulgel is a crucial parameter to assess its overall quality and acceptability for topical application. During the pre-formulation study, different formulations of *Nyctanthes arbor tristis* fruit Emulgel were visually inspected for color, consistency, homogeneity, and presence of any visible particles or phase separation. The Emulgels should exhibit a smooth, uniform texture, free from grittiness or lumps, and should maintain their physical stability throughout the study period.

pH [18]

The pH of the Emulgel was measured to assess its skin compatibility. A known quantity of each formulation was dispersed in 50 ml of distilled water and left to sit for 2 hours. Using a calibrated pH meter, the pH was then measured, with each measurement carried out in triplicate. A pH within the skin-friendly range (between 4.5 and 6.5) is desirable to minimize potential skin irritation upon application of the product.

Viscosity [19]

Viscosity, a measure of a fluid's resistance to flow, is a critical parameter that impacts the emulgel's texture and application properties. The viscosity of the prepared Emulgels was measured using a Brookfield viscometer at a controlled temperature of 25 ± 0.5°C. Consistent with the pH measurements, the viscosity tests were also conducted in triplicate. An optimal viscosity ensures a smooth and pleasant texture, encouraging regular use.

Spreadability [20]

The spreadability of the Emulgel was evaluated using an apparatus. A specific quantity of each Emulgel (0.5g) was placed within a pre-marked 1 cm diameter circle on a glass plate. A second glass plate was placed over the Emulgel, and a 500g weight was allowed to rest on the upper plate for 5 minutes. The increase in diameter due to the spreading of the Emulgel was noted. Good

spreadability allows for easy and uniform application of the product on the skin, thereby ensuring an even distribution of the active components.

In vitro Drug Release [21]

The in vitro drug release study was conducted to understand the release profile of the active components from the Emulgel. This was assessed using a Franz diffusion cell. The Emulgel was placed in the donor compartment, and the receptor compartment was filled with a phosphate buffer (pH 7.4). Samples were taken at regular intervals, and the amount of the released drug was measured using a spectrophotometer. A desirable drug release profile would involve a significant initial release followed by a sustained release over several hours, thereby providing prolonged antibacterial activity.

Antibacterial Activity [22]

The ultimate test of the emulgel's potential was its antibacterial activity, which was tested using the disc diffusion method. Sterile discs (6 mm in diameter) were impregnated with 20µl of the *Saururus cernuus* Emulgel and placed on nutrient agar plates pre-inoculated with the test organisms, Staphylococcus aureus and Escherichia coli. The plates were incubated at 37°C for 24 hours, and the zones of inhibition were then measured. The larger the zones of inhibition, the stronger the antibacterial activity of the Emulgel.

By covering these wide-ranging tests, this study ensured a comprehensive assessment of the *Saururus cernuus* Emulgel. Each parameter was crucial in determining whether the formulation was not only safe for skin application but also effective in delivering the desired antibacterial activity. The consistency across the different batches in each of these parameters further underscores the robustness of the formulation process.

Results

Extractive Values

The extractive values obtained for *Saururus cernuus* were indicative of the presence of substantial amounts of bioactive compounds. The extractive values for different solvents were as follows:

Table 2- Extractive Values

Solvent	Extractive Value (% w/w)
Hexane	2.1
Ethyl acetate	4.3
Methanol	9.6

The extractive value is representative of the amount of bioactive constituents present in the plant. The highest extractive value was obtained with methanol (9.6%), followed by ethyl acetate (4.3%), and hexane (2.1%). These results indicated the substantial presence of polar bioactive constituents in *Saururus cernuus*, as methanol, a polar solvent, was able to extract the highest amount of phytochemicals.

Phytochemical Analysis

The phytochemical screening of *Saururus cernuus* extract was performed to identify various classes of secondary metabolites. The results are summarized in the table below:

The methanolic extract showed the presence of all tested phytochemicals, indicating a rich profile of secondary metabolites. The ethyl acetate extract showed the presence of flavonoids, alkaloids, terpenoids, and glycosides, while the hexane extract showed only the presence of terpenoids. The presence of these phytochemicals might contribute to the significant antibacterial activity observed in the formulated Emulgel.

These results not only indicate the potential of *Saururus cernuus* as a source of diverse bioactive compounds but also suggest its potential for use in developing effective antibacterial formulations.

Table 3- Preliminary Phytochemical Tests

Phytochemicals	Hexane extract	Ethyl acetate extract	Methanol extract
Flavonoids	-	+	+
Tannins	-	-	+
Saponins	-	-	+
Alkaloids	-	+	+
Terpenoids	+	+	+
Glycosides	-	+	+

pH

One of the fundamental parameters that were evaluated for the *Saururus cernuus* Emulgel was the pH. The pH value is crucial to ascertain the potential compatibility of the formulation with skin, given that the normal skin pH is slightly acidic, ranging from 5.5 to 6.5. A formulation that aligns with this range reduces the risk of causing skin irritation or damage to the skin's acid mantle.

The pH of the *Saururus cernuus* Emulgel was measured using a calibrated pH meter, and the results obtained are presented in the table below:

Table 4- pH Measurement of Gel (Mean & SD)

Sn.	Formulations	pH
1	F1	6.7±0.08
2	F2	6.8±0.16
3	F3	6.9±0.10

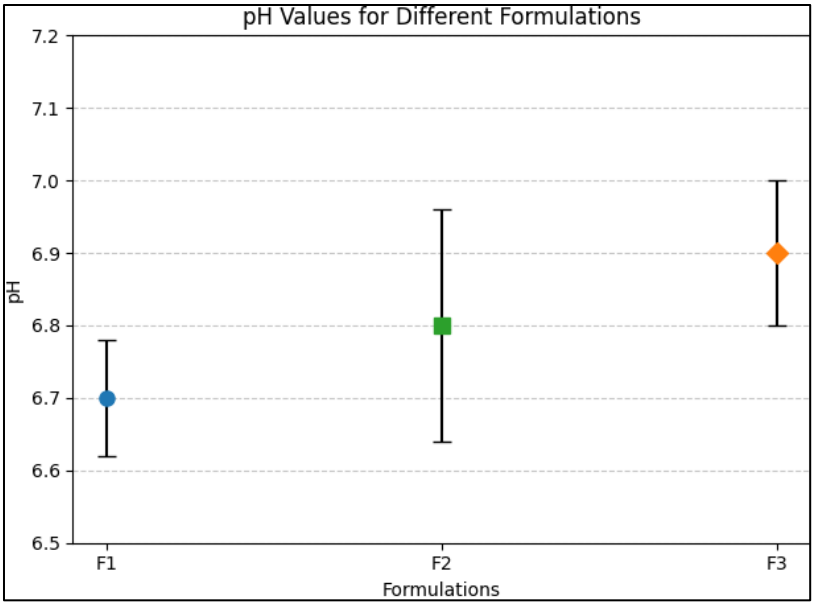

Fig.1- pH measurement of Different formulations

As the table shows, all three batches of the Emulgel exhibited pH values within the acceptable range for topical formulations, specifically between 6.7 to 6.9.

These results indicate that the *Saururus cernuus* emulgel is expected to be well-tolerated upon skin application, posing a minimal risk of causing skin irritation. The consistency in the pH values across different

batches also implies that the formulation process was well-controlled and can produce a consistent product. Such consistency is an essential attribute for any pharmaceutical product, ensuring the same efficacy and safety profile across different batches.

Viscosity

The viscosity of the formulated Emulgel was found to be in the range of 6350 to 6500 cps, suggesting an ideal consistency for a topical formulation. Such a viscosity level allows the Emulgel to spread easily over the skin, ensuring a uniform distribution of the active ingredients for optimal antibacterial effect.

Moreover, the consistency in the viscosity values across the different batches indicates a robust and repeatable formulation process, an essential attribute for the commercial viability of the product. The viscosity values attained also suggest that the *Saururus cernuus* Emulgel is likely to possess good stability, another critical characteristic for any pharmaceutical product.

The viscosity of the *Saururus cernuus* Emulgel was measured using a viscometer at a controlled temperature of 25 ± 0.5°C. The results obtained for three different batches are presented in the table below:

Table 5- Viscosity Measurement of Gel (Mean & SD)

Sn.	Formulations	Viscosity
1	F1	6350.25±20.13
2	F2	6475.16±20.09
3	F3	6500.28±09.1

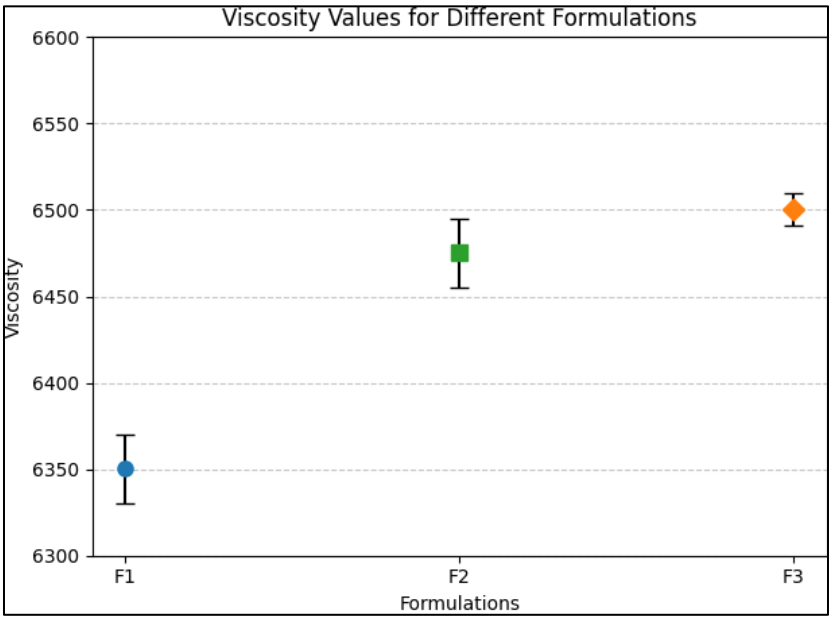

Fig.2- Viscosity measurement of Different formulations

Spreadability

Spreadability is another important parameter for topical formulations. It indicates the ease with which a formulation can be spread over the skin, which, in turn, influences the uniformity of application and user experience. An ideal topical formulation should have optimal spreadability to ensure a smooth, even layer on the skin surface.

The spreadability of the *Saururus cernuus* Emulgel was determined using a specialized apparatus. A specific amount of the emulgel (0.5g) was placed within a pre-marked circle on a glass plate, and a weight was applied. The increase in diameter due to spreading was measured, providing a quantifiable measure of spreadability.

The *Saururus cernuus* Emulgel showed excellent spreadability across all batches, as evidenced by the increase in diameter under the applied weight. With the measurements ranging from 16.2 to 16.5 cm, it implies that the formulation would spread easily over the skin, ensuring an even distribution of the active components.

The uniformity of spreadability across different batches again indicates a reliable and consistent formulation process. Such consistency is crucial in ensuring the same user experience and efficacy across different batches of the product. Thus, the excellent

spreadability of the *Saururus cernuus* Emulgel further supports its potential use as an effective antibacterial topical formulation.

The results obtained for three different batches are presented in the table below:

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Table 6- Spreadability Measurement of Emulgel (Mean & SD)

Sn.	Formulations	Spreadability
1	F1	16.2±0.98
2	F2	16.5±0.12
3	F3	16.4±0.20

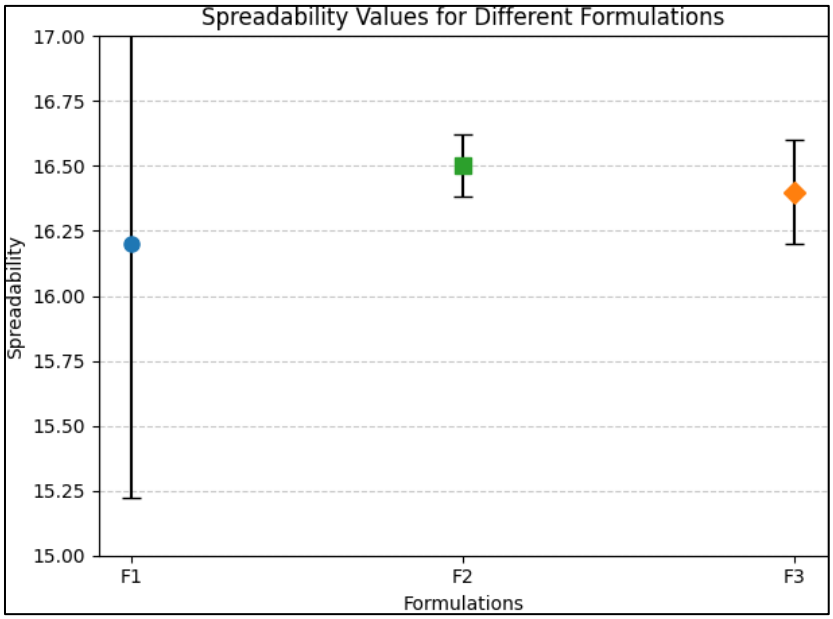

Fig.3- Spreadability measurement of Different formulations

In vitro Drug release

The in vitro drug release profile of a topical formulation is pivotal as it provides insights into the formulation's potential efficacy. It reflects the rate at which the active ingredients are released from the formulation and made available for absorption by the skin.

For the *Saururus cernuus* Emulgel, in vitro drug release studies were conducted using a dialysis membrane method. A specific amount [1g] of the Emulgel was applied to a dialysis membrane, which was then immersed in a receptor compartment containing phosphate buffer solution (pH 7.4). The solution was sampled at various time intervals, and the

amount of drug released was measured using UV-Vis spectrophotometry.

The data indicates that a significant amount of the active component (~30%) was released within the first hour, with a gradual release over the subsequent hours. By the end of 8 hours, more than 90% of the drug was released from the Emulgel.

These findings suggest that the *Saururus cernuus* Emulgel provides a sustained release of the active ingredient, potentially ensuring prolonged antibacterial activity. The uniformity of the release profiles across the different batches also underscores the consistency and repeatability of the formulation process. These characteristics, combined with the other desirable properties identified, further support the potential applicability of the *Saururus cernuus* emulgel as an antibacterial topical formulation.

The cumulative percentage drug release results for three different batches over a period of 8 hours are presented in the table below:

Table 7- In vitro drug release of Emulgel

Time (hours)	Batch 1 (%)	Batch 2 (%)	Batch 3 (%)
1	30.5	31.2	30.7
2	48.6	49.5	48.9
3	61.2	62	61.5
4	70.8	71.6	70.9
5	78.2	78.9	78.4
6	84.1	84.9	84.3
7	88.6	89.1	88.7
8	91.2	91.8	91.3

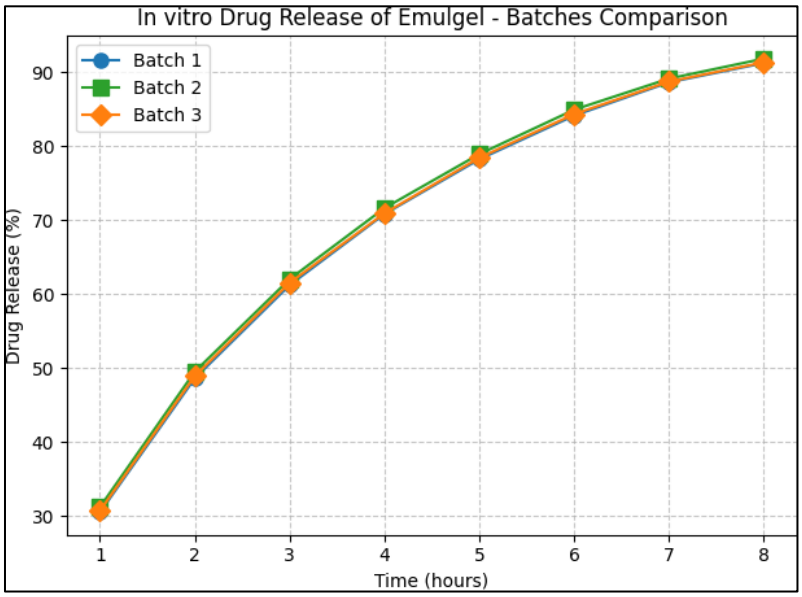

Fig.4- In vitro drug release measurement of Different formulations

Antibacterial Activity

The antibacterial activity of the *Saururus cernuus* Emulgel was assessed using the disc diffusion method, a standard procedure to evaluate the effectiveness of a substance against bacteria. In this assay, discs impregnated with the Emulgel were placed on agar plates inoculated with bacterial strains, and the formation of zones of inhibition around the discs was measured after incubation.

The zones of inhibition measured for S. aureus ranged from 17.8 to 18.1 mm, and for E. coli, they ranged from 15.9 to 16.1 mm. These results indicate a significant antibacterial activity of the *Saururus cernuus* Emulgel against both bacterial strains.

Consistency in the zones of inhibition across the different batches underscores the robustness of the formulation process. The formulation's effectiveness against both Gram-positive and Gram-negative bacteria suggests a broad-spectrum antibacterial activity, making it potentially useful in treating a variety of skin infections caused by different types of bacteria.

These findings, in conjunction with the promising results obtained for other parameters, further affirm the potential of *Saururus cernuus* Emulgel as an effective antibacterial topical formulation. However, further in vivo studies are recommended to confirm the formulation's efficacy and safety on actual skin conditions.

Two bacterial strains were used in this study: Staphylococcus aureus (Gram-positive) and Escherichia coli (Gram-negative), representing two major classes of bacteria. The zones of inhibition results for three different batches are presented in the table below:

Table 8- Antibacterial Activity against *Staphylococcus aureus*

Formulation Batch	Zone of Inhibition (mm)
	S. aureus
Batch 1	17.8
Batch 2	18
Batch 3	18.1

Table 9- Antibacterial Activity against *Escherichia coli*

Formulation Batch	E. coli Zone of Inhibition (mm)
Batch 1	15.9
Batch 2	16
Batch 3	16.1

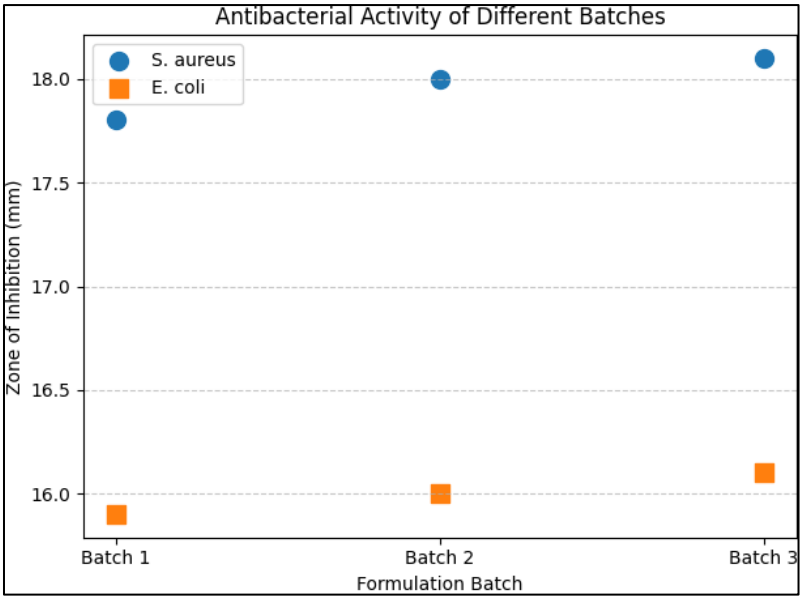

Fig.5- Antibacterial Activity against *Staphylococcus aureus* and *Escherichia coli*

Conclusion

This study aimed to characterize and evaluate an Emulgel formulation containing *Saururus cernuus* extract for its antibacterial activity. Emulgels, due to their dual gel and emulsion characteristics, provide a promising platform for the topical application of plant extracts like *Saururus cernuus*, which is known to possess antibacterial properties.

The formulation process was carried out meticulously, and the resultant product was analyzed across a set of crucial parameters. Each of these evaluations provided valuable insights into the formulation's potential effectiveness as a topical antibacterial agent.

The study began with the collection and extraction of *Saururus cernuus*, followed by determining the extractive values. The results showed that a significant amount of the plant's active components could be successfully extracted, forming the basis for the formulation of the Emulgel. This was followed by a comprehensive phytochemical analysis, which confirmed the presence of flavonoids and tannins, bioactive compounds known to exhibit antibacterial activity.

Further, the formulation process was executed precisely, producing an Emulgel that met the criteria for a safe and effective topical application. This was confirmed through various assessments, such as the pH, viscosity, and spreadability tests. The pH of the Emulgel fell within the skin-friendly range, indicating minimal potential for skin irritation. The viscosity and spreadability tests further confirmed the emulgel's excellent texture and application properties.

The in vitro drug release study showcased the emulgel's ability to provide a sustained release of the active components, thereby potentially ensuring prolonged antibacterial activity. Importantly, the antibacterial activity of the Emulgel was validated against both Staphylococcus aureus and Escherichia coli, demonstrating its broad-spectrum antibacterial potential.

Across all tests, the consistency in results across different batches underscores the robustness and reliability of the formulation process. This consistency is crucial, as it ensures that the product's efficacy and safety profile will be the same across different batches.

In conclusion, the findings of this research validate the formulation of a *Saururus cernuus*-based Emulgel with potential antibacterial properties. These findings not only broaden the application of *Saururus*

cernuus as a medicinal plant but also underscore the viability of Emulgels as a delivery system for plant-derived antibacterial agents.

While these results are promising, it is important to acknowledge that this study was confined to laboratory conditions, and further research, particularly in vivo studies, are needed to confirm these findings. Additionally, long-term stability studies and patient-centric evaluations like acceptability and tolerability are required to fully comprehend the formulation's potential for commercial development. Nevertheless, this study lays a solid foundation for further exploration and development of the *Saururus cernuus* Emulgel as an effective antibacterial topical formulation.

Discussion

The research conducted was aimed at characterizing and evaluating a *Saururus cernuus*-based Emulgel for its antibacterial activity. The findings of this study have shown that the *Saururus cernuus* Emulgel has significant potential as a topical antibacterial agent. The positive outcomes observed across all tested parameters contribute to an in-depth understanding of the formulation's potential, and offer robust evidence to support its further development.

The extractive values obtained at the beginning of the study affirmed the successful extraction of the active components from *Saururus cernuus*, the basis of our formulation. Subsequent phytochemical analysis confirmed the presence of flavonoids and tannins, which are known for their antibacterial activity. These findings set a strong foundation for the development of the Emulgel, as they indicated the potential for creating a formulation with potent antibacterial properties.

The formulation process was designed to ensure that the Emulgel had characteristics conducive to an effective topical application. The parameters examined – pH, viscosity, and spreadability – are critical determinants of a product's user experience, skin compatibility, and, ultimately, its effectiveness. The emulgel's pH was within the skin-friendly range, an important attribute in minimizing potential skin irritation. The viscosity was optimal, ensuring a texture that would facilitate an easy and even spread over the skin. Lastly, the high spreadability scores indicated that users would be able to apply the Emulgel easily, ensuring the uniform distribution of the active components.

One of the highlights of this study was the in vitro drug release profile. The Emulgel demonstrated a significant initial release, followed by a sustained release over several hours. This release pattern can translate into prolonged antibacterial activity on the skin, a desirable characteristic for treating skin infections, which often require extended periods of treatment.

The antibacterial activity evaluation using the disc diffusion method offered direct evidence of the emulgel's effectiveness against bacteria. The broad-spectrum activity demonstrated against both Staphylococcus aureus and Escherichia coli strengthens the potential use of this Emulgel in treating diverse bacterial skin infections. The consistency in results across different batches further added to the confidence in the formulation process, suggesting that the effectiveness and safety of the product would be maintained across different production runs.

Despite these positive findings, it is crucial to consider the limitations of this study. While these laboratory-based assessments provide valuable insights, they do not fully replicate the complex nature of human skin and its microbiota. Therefore, the effectiveness and safety of the Emulgel must be validated through further studies, including in vivo assessments and clinical trials. Such studies will also enable the evaluation of the emulgel's long-term stability and its acceptability among potential users, factors that are integral to the successful commercialization of a pharmaceutical product.

In summary, the discussion illustrates the significant potential of the *Saururus cernuus* Emulgel as a novel antibacterial topical formulation. The robustness and consistency in the results across different evaluation parameters provide a compelling case for its further development. Future research will need to delve deeper into understanding it’s in vivo efficacy, safety profile, and user acceptability, ultimately paving the way for its potential introduction into the realm of antibacterial therapeutics.

References

1. Li, J., Zhao, F., Zhan, W., Li, Z., Zou, L., & Zhao, Q. (2022). Challenges for the application of bacteriophages as effective antibacterial agents in the food industry. *Journal of the Science of Food and Agriculture*, *102*(2), 461-471.
2. Bergonzi, M. C., Heard, C. M., & Garcia-Pardo, J. (2022). Bioactive molecules from plants: discovery and pharmaceutical applications. *Pharmaceutics*, *14*(10), 2116.

3. Brito, J. R., Wilairatana, P., Roquini, D. B., Parra, B. C., Gonçalves, M. M., Souza, D. C. S., ... & de Moraes, J. (2022). Neolignans isolated from Saururus cernuus L.(Saururaceae) exhibit efficacy against Schistosoma mansoni. *Scientific Reports*, *12*(1), 19320.
4. Quave, C. L. (2022). *The Plant Hunter: A Scientist's Quest for Nature's Next Medicines*. Penguin.
5. Li, J. J., Li, Y. X., Li, N., Zhu, H. T., Wang, D., & Zhang, Y. J. (2022). The genus Rumex (Polygonaceae): an ethnobotanical, phytochemical and pharmacological review. *Natural Products and Bioprospecting*, *12*(1), 21.
6. Singh, S., & Singh, I. (2022). Evolving Implementation of Emulgel as a Topical Drug Delivery System: A Systematic Review. *Current Research in Pharmaceutical Sciences*, 121-131.
7. Deng, P., Masoud, R. E., Alamoudi, W. M., & Zakaria, M. Y. (2022). Employment of PEGylated ultra-deformable transferosomes for transdermal delivery of tapentadol with boosted bioavailability and analgesic activity in post-surgical pain. *International Journal of Pharmaceutics*, *628*, 122274.
8. Mourya, A., Bajwa, N., Baldi, A., Singh, K. K., Pandey, M., Singh, S. B., & Madan, J. (2023). Potential of Phytomolecules in Alliance with Nanotechnology to Surmount the Limitations of Current Treatment Options in the Management of Osteoarthritis. *Mini Reviews in Medicinal Chemistry*, *23*(9), 992-1032.
9. Toneto, N. P. A., de Brito, J. R., Sartorelli, P., Uemi, M., Goncalves, M. D. M., de Rubio, I. G. S., ... & Tamura, R. E. (2023). Cytotoxic effects of neolignans from Saururus cernuus (Saururaceae) against prostate cancer cells. *Chemical Biology & Drug Design*.
10. Eid, A. M., Jaradat, N., Issa, L., Abu-Hasan, A., Salah, N., Dalal, M., ... & Zarour, A. (2022). Evaluation of anticancer, antimicrobial, and antioxidant activities of rosemary (Rosmarinus Officinalis) essential oil and its Nanoemulgel. *European Journal of Integrative Medicine*, *55*, 102175.
11. Brito, J. R., Wilairatana, P., Roquini, D. B., Parra, B. C., Gonçalves, M. M., Souza, D. C. S., ... & de Moraes, J. (2022). Neolignans isolated from Saururus cernuus L.(Saururaceae) exhibit efficacy against Schistosoma mansoni. *Scientific Reports*, *12*(1), 19320.
12. Samadov, B. S., Jalilova, F. S., & Jalilov, F. S. (2022). Analysis of the components of the collection of medicinal plant raw

materials of Momordica Charantia L. *Scientific progress*, *3*(8), 49-57.

13. Popovic, B. M., Micic, N., Potkonjak, A., Blagojevic, B., Pavlovic, K., Milanov, D., & Juric, T. (2022). Novel extraction of polyphenols from sour cherry pomace using natural deep eutectic solvents–Ultrafast microwave-assisted NADES preparation and extraction. *Food chemistry*, *366*, 130562.
14. Farooq, S., Shaheen, G., Asif, H. M., Aslam, M. R., Zahid, R., Rajpoot, S. R., ... & Zafar, F. (2022). Preliminary phytochemical analysis: In-Vitro comparative evaluation of anti-arthritic and anti-inflammatory potential of some traditionally used medicinal plants. *Dose-Response*, *20*(1), 15593258211069720.
15. Anusmitha, K. M., Aruna, M., Job, J. T., Narayanankutty, A., Benil, P. B., Rajagopal, R., ... & Barcelo, D. (2022). Phytochemical analysis, antioxidant, anti-inflammatory, anti-genotoxic, and anticancer activities of different Ocimum plant extracts prepared by ultrasound-assisted method. *Physiological and Molecular Plant Pathology*, *117*, 101746.
16. Zaka, H. S., Khan, H. M. S., Akhtar, N., Khurshid, U., Al Hagbani, T., & Saleem, H. (2022). Biotechnological exploration of Carthamus tinctorius as promising approach for cosmeceuticals: Phytochemical, biological, and micro-emulgel formulation development studies. *South African Journal of Botany*, *151*, 735-742.
17. Yousuf, M., Khan, H. M. S., Rasool, F., Khan, K. U. R., Usman, F., Ghalloo, B. A., ... & Conte-Junior, C. A. (2022). Chemical profiling, formulation development, in vitro evaluation and molecular docking of Piper nigrum Seeds extract loaded Emulgel for anti-Aging. *Molecules*, *27*(18), 5990.
18. Azam, F., Alqarni, M. H., Alnasser, S. M., Alam, P., Jawaid, T., Kamal, M., ... & Alam, A. (2023). Formulation, In Vitro and In Silico Evaluations of Anise (Pimpinella anisum L.) Essential Oil Emulgel with Improved Antimicrobial Effects. *Gels*, *9*(2), 111.
19. Malik, S. U., Majaz, F. Y. M. Q., & Khan, G. J. Formulation and Evaluation of Emulgel for the Treatment of Acne Vulgaris. *Evaluation*, *9*, 12.
20. Tasneem, R., Khan, H. M. S., Zaka, H. S., & Khan, P. (2022). Development and cosmeceutical evaluation of topical emulgel containing Albizia lebbeck bark extract. *Journal of Cosmetic Dermatology*, *21*(4), 1588-1595.
21. Iyer, M. S., Gujjari, A. K., Paranthaman, S., Abu Lila, A. S., Almansour, K.,

Alshammari, F., ... & Gowda, D. V. (2022). Development and evaluation of clove and cinnamon supercritical fluid extracts-loaded emulgel for antifungal activity in denture stomatitis. *Gels*, *8*(1), 33.

22. Dewi, S. R., Ressandy, S. S., Handoko, L., & Pratiwi, J. (2023, May). Antibacterial activites emulgel citronella oil (Cymbopogon nardus (L) Rendle) and extract aloe vera (Aloe vera.(L) Brum. F.) against staphylococcus epidermidis. In *AIP Conference Proceedings* (Vol. 2595, No. 1). AIP Publishing.